Digital radio: what's it all about?

A glimpse into the world of digital radio

I think it's safe to assume that most amateurs are aware of the various modulation modes that we have at our disposal such as AM, FM, SSB, CW, SSTV etc, just to name a few.

Back in the day, many amateurs in the UK first got onto 2m and, later, 70cm by modifying surplus professional mobile radio (PMR) [1] equipment, which has been around in the UK since 1947. As time went on, radio amateurs took advantage of surplus PMR radios when they came on to the market. Many were converted for the VHF and UHF amateur bands, and several articles appeared in amateur radio magazines showing how this could be done.

Digital radio communication has been around for a while. On the amateur bands, text-based data communications became popular in the 1980s using terminal node controllers (TNC) with their characteristic sounds. Lists of nodes seemed to be published everywhere. Broadcasters, particularly for satellite TV, have used digital signals for many years.

The introduction of digital voice PMR products has brought great benefits to the users of professional radio. Digital modulation provides a wide range of advantages by enabling the exchange of more complex information, resistance to radio interference and arguably better audio quality. It wasn't long before encryption was added to provide a secure and safe way of converting speech to transmissions. The UK emergency services largely transferred over to digital around the turn of the century, having previously migrated from just above Band 2 (88-108MHz) to 'high band' (~140-180MHz) VHF, as well as UHF.

Digital radio is, however, bringing a degree of complexity in that there are many different types of protocols now on offer – DMR [2], dPMR [3], NXDN [4], TETRA [5], P25 [6] to name but a few – some of which are standardised and some proprietary. D-Star (Digital Smart Technologies for Amateur Radio) [7] was developed by amateurs in collaboration with the Japan Amateur Radio League (JARL); it offers digital voice and data comms either direct or via an internet backbone for longer distances (potentially world-wide, or at least anywhere close to an internet connection). The most recently launched system, Yaesu's System Fusion [8], offers functions that are broadly comparable to D-Star and DMR.

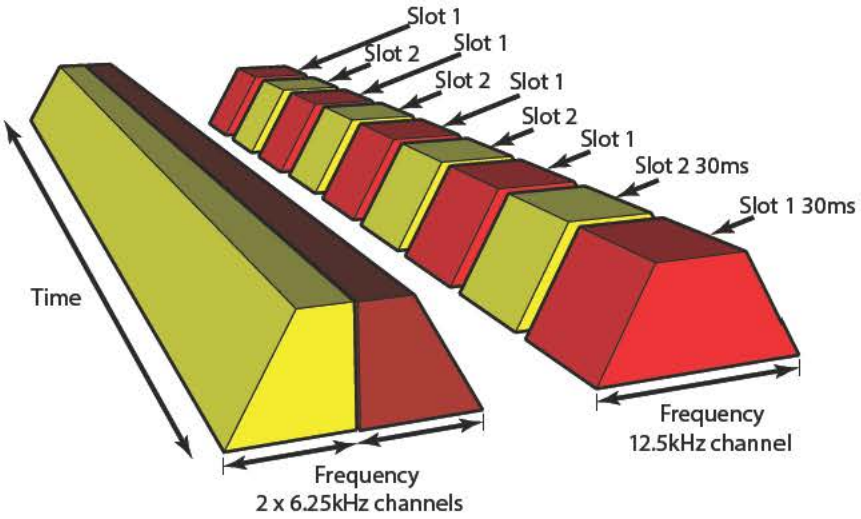

FIGURE 1: Left frequency division multiplexing (conventional channels); right time division multiplexing (channel divided into time slots).

None of these protocols are compatible with each other and all bring different attributes to the table. All, however, are more efficient than analogue in terms of use of spectrum. They can also improve coverage and fringe area voice quality, due to the efficiencies of digital processing and error correction. But as a digital system reaches the limit of its range it tends to stop working quite suddenly when errors can no longer be corrected – this is sometimes known as the 'digital cliff' [9].

The DMR standard was first published in 2005 and has been widely adopted by radio manufacturers and users worldwide. Research by the Digital Mobile Radio Association has concluded that DMR has become the leading digital PMR technology in operations-critical sectors such as the transport and industrial sectors. They claim to have more terminals (handhelds, vehicle-mounted, base station etc) in use than any other digital technology. Major manufacturers of DMR equipment include Motorola, Kenwood, Vertex, Tait, Simoco, Hytera and others; 'copies' are being made by a number of Chinese manufacturers. D-Star has been driven largely by Icom, until recently the only major manufacturer making suitable equipment, however Kenwood has now started making D-Star compatible radios. Only Yaesu makes System Fusion.

Largely thanks to the availability of ex-PMR equipment and the lower cost of new equipment thanks to economies of scale, many amateurs worldwide have taken up DMR. One of the principal benefits of DMR is that it enables a single 12.5kHz channel to support two simultaneous and independent calls, achieved using a system called 'time division multiple access', described next.

Time and frequency division multiplexing

Broadly speaking there are two underlying technologies to all of the various digital radio protocols that allow multiple users in a given chunk of spectrum:

- Frequency Division Multiple Access (FDMA) – used by systems including NXDN and dPMR
- Time Division Multiple Access (TDMA) – used by DMR, TETRA, P25 Phase 2 and others.

Figure 1 shows how FDMA and TDMA compare. In FDMA (left), a channel corresponds to a frequency band and channels are assigned to individual users. So, in FDMA the entire bandwidth is divided in different frequency bands or channels that (perhaps on request) are allowed to each user. No user can share the same frequency band at the same time. Small 'guard bands' are maintained between adjacent signals to minimise cross-talk between channels. User A has 100% use of a small slice of spectrum (here shown as 6.25kHz) and user B has 100% use of another similar small slice of spectrum. They thus share a total of 12.5kHz.

On the other hand, TDMA (right) divides up spectrum using time slots; user A gets a few

milliseconds of access to the 'full' bandwidth (30ms of 12.5kHz in this example), then its user B's turn. Because both user A and user B can both get access to the same 12.5kHz channel using TDMA techniques, the channel usage is the same as the FDMA example where 12.5kHz is shared between user A and user B each in 6.25kHz chunks

Different users can transmit or receive messages, one after the other in the same bandwidth but at different time slots. Each user occupies a cyclically repeating time slot and a TDMA channel may be thought of as a particular time slot that recurs regularly.

A very simple example to illustrate this principle can be two users each speaking a rhyme. Take one saying "Mary had a little lamb" in slot 1 and the other reciting "Hickory dickory dock" in slot 2. Each sender's information (speech) is cut into small packets of data and transmitted one after the other. So it might sound something like Mary Hickory had dickory a dock little the lamb mouse. In reality the time slots are very short (eg 30ms) but this does illustrate the principle.

Once the packets are received at the other end, the digital processing reassembles them into normal speech.

- FDMA isn't limited to two channels: for example, you can think of all the 2m repeater outputs side by side as a form of FDMA that divides 145.600MHz to 145.7875MHz into 16 separate 12.5kHz channels (RV48-RV63).
- Similarly, TDMA is not limited to two time slots – the TDMA-based GSM mobile phone system uses eight time slots per 'frame' (group of slots) so that it can support multiple users on the same frequency, or offer more bandwidth to certain users by giving them more slots.
- FDMA and TDMA essentially provide the same amount of capacity (channels) in the same amount of frequency spectrum, they just divide the spectrum in different ways.

Which system?

It is important to understand some basic differences in the systems' technology in order to make the right choice for an application. Some differences in specific products are the result of the way different vendors have implemented features. Others are due to fundamental differences in the underlying technology used by the protocol. These underlying differences impact system scalability, power efficiency, feature possibilities and both access to and use of spectrum. DMR uses TDMA and many of its advantages come from this choice.

D-Star has the ability to call a station by simply entering their callsign in a field in the radio. Repeaters can be connected to each other or to 'conference rooms' by the user.

Yaesu System Fusion can connect to other Fusion systems using Wires-X. In a way it is similar in use to Echolink, as the radio display updates as you navigate connections, so you can easily see what you are connecting to. Most Fusion radios also come with Group Monitor (GM), which sends out a request to see which radios are monitoring.

DMR does have a limitation whereby connections are limited to what the sysop (system operator) has configured, and usually requires the radio to be reprogrammed when new connections are needed or added.

I've had a few surprises at the number of RNARS members who are on DMR and had some interesting contacts elsewhere.

Getting started

With most common amateur digital radio systems there are a number of things you have to do before you can get involved (Yaesu System Fusion is a notable exception). D-Star and DMR both require one-time registration before use. I'll explore DMR here; D-Star is *broadly* similar although the details are different.

To get started on DMR you first have to obtain an ID number. This can be obtained free from DMR-MARC **[10]**. A DMR ID is similar to a phone number. You program it into your radio then, a bit like a phone's Caller ID, others will see you show up on their displays. If the radio is programmed in a certain way, then the call sign and/or name belonging to the transmitted ID appears in the display. One of my radios has over 800 active DMR UK calls in the memory. Live logs are available online so that you can see if you are really accessing the repeater(s) as well as who else was on the air at the time.

DMR has a capability to have Talk Groups that can be local, regional, national or world-wide – and even language specific. With the scanning facilities it is possible to hear activity on the channels such that you shouldn't miss your friends when they call you.

Setting up a digital radio can be complex, but there are now numerous guides on the internet and various downloadable files to help you with the process. Unfortunately there is some division into various 'camps' even within fraternities using a single system (eg DMR), with the practical upshot that if you side with one group you may not be able to talk to others who use the same system. This is quite separate from the fundamental incompatibilities between the different systems (D-Star, DMR, Fusion…).

One of the greatest joys of the new digital radios is the way that the repeaters can be linked to the internet and provide contacts with excellent voice quality over vast distances. There is something very special about sitting in your back garden with a little handheld, chatting away to a fellow amateur on another continent! Some digital systems also support data and picture transfer – even with a camera built into a hand mic – making it possible to send photos effortlessly, either locally or over a wider area.

Conclusion

As the title suggested, this is only a glimpse into the world of digital two-way radio. You can discover a completely new side to amateur radio that was never before possible with conventional CW, AM, SSB or FM systems. Gone are the days of stupid signal reports like "you are 5 and 1". How can anybody be perfectly readable when signals are barely perceptible? DMR, for example, has just three states of signals: perfectly clear and very good quality; broken up digital; and no signal at all.

If only Marconi knew what he started! What's it all about? The answer is the efficient use of the spectrum.

Acknowledgements

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Websearch

[1] also known as private mobile radio
[2] Digital Mobile Radio, an open standard, see https://en.wikipedia.org/wiki/Digital mobile radio
[3] Digital private mobile radio, see https://en.wikipedia.org/wiki/Digital private mobile radio
[4] NXDN is an open standard 'common air interface' developed by Icom and Kenwood, see https://en.wikipedia.org/wiki/NXDN
[5] Terrestrial Trunked Radio, see https://en.wikipedia.org/wiki/Terrestrial Trunked Radio
[6] Project 25, or APCO 25, digital comms standards widely used in North America, see https://en.wikipedia.org/wiki/Project 25
[7] see www.d staruk.co.uk/
[8] see https://systemfusion.yaesu.com/what is system fusion/
[9] https://en.wikipedia.org/wiki/Cliff effect
[10] www.dmr marc.net/
[11] Royal Naval Amateur Radio Society: www.RNARS.org.uk

There are many dedicated websites, Facebook groups and other online resources for DMR, D Star, Yaesu System Fusion and other systems a web search will help you find them.

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